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P-3500

Digital

Strain Indicator

-Instruction Manual-

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INSTRUCTION MANUAL
MODEL P-3500 STRAIN INDICATOR

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Model P-3500 Strain Indicator

1.0 GENERAL DESCRIPTION

The Model P-3500 Strain Indicator is a portable, battery-powered precision instrument for use with resistive strain gages and transducers. The P-3500 will accept full-, 1/2- and 1/4-bridge inputs, and all required bridge completion components for 120-ohm and 350-ohm bridges are provided. Strain gages are normally connected via the front panel binding posts. Transducers are normally connected via a front panel transducer connector. Remote-sense capability is provided at the transducer connector to enable full six-wire operation.

The P-3500 will accept gage factors of 0.500 to 9.900, and gage factor is settable to an accuracy of 0.001 by a front panel 10-turn potentiometer. Gage factor is displayed on the LCD display.

Operating controls of the P-3500 are simple and straightforward. The color-coded push buttons allow the operator to determine the operating mode at a glance. A minimum of operator training is required.

The P-3500 operates from an internal battery pack consisting of six replaceable alkaline "D" cells. Battery life is approximately 250 to 300 hours of continuous use. An AC adapter is available for situations in which the unit is in continuous laboratory use.

CAUTION: When it becomes necessary to clean the P-3500, do not use solvents on the front panel or on the information label inside the lid.

2.0 SPECIFICATIONS

Range and Display: Direct-reading liquid crystal display.
±19 999με at GF <6.000, MULT X1.
$\pm 19\ 999\mu\epsilon \times \frac{6.000}{GF}$ at GF >6.000, MULT X1.
±199 990με at GF <6.000, MULT X10.
$\pm 199\ 990\mu\epsilon \times \frac{6.000}{GF}$ at GF >6.000, MULT X10.

Overload indication: All zero display and flashing arrow in upper left of display.

Resolution: 1με at MULT X1.
10με at MULT X10.

Accuracy: ±0.05% rdg ±3με for Gage Factor ⩾1.000, MULT X1.
±0.05% rdg ±10με for Gage Factor ⩾1.000, MULT X10.

Balance Range:

Coarse balance: ±2000με ±1%, ±4000με ±1% (GF=2.000).

Fine balance: 10-turn precision potentiometer ±1050με min. (GF=2.000).
Zero position of potentiometer calibrated for zero, ±2με.
Balance is accomplished by electronic voltage injection at the amplifier input.
Balance controls do not load bridge circuit or compromise the measurement range.

Gage Factor:

Range: 0.500 to 9.900 with resolution of 0.001.

Accuracy: ±0.02% max. for Gage Factor >1.000.

Bridge Excitation: 2.00 Vdc ±0.1%.
Temperature stability ±0.02%/°C.
(All readings are fully ratiometric and accuracy not degraded by variation in excitation level.)

Amplifier:

Temperature effect on zero:	±1.0 μV/°C RTI max.
Temperature effect on span:	±0.005%/°C max.
Warm-up drift:	Less than ±3 counts at GF=2.00 from turn-on to 10 minutes.
Random drift at constant ambient temperature:	Less than ±1 count at GF=2.000.
Common-mode rejection:	Greater than 90 dB at 50-60 Hz.
Input impedance:	Greater than 30 megohm differential and common mode.

Input Circuits: 60-2000 ohm 1/2 or full bridge. Internal dummy gages are provided for 120-ohm and 350-ohm 1/4 bridges.

Calibration: Shunt calibration resistors are provided across internal 120-ohm and 350-ohm dummy gages to simulate 5000με ±0.05%. Connections are provided for use of an optional internal or external calibration resistor. (See paragraphs 5.5 and 6.1.)

Analog Output:

Linear output:	±2.50V max.; adjustable from 40 μV/με to 440 μV/με nominal.
Output load:	2 KΩ min. resistance.
Bandwidth:	DC to 4 kHz −3 dB nominal.
Output noise:	Less than 400 μV rms at 40 μV/με output level.

Remote Sense: Remote sense connections provided at transducer connector.

Remote sense error:	Less than 0.001%/ohm of lead resistance.
Recommended maximum lead resistance:	35 ohm.

Power:	Six alkaline "D" cells. Approximate life 250-300 hours. Power is automatically off when cover is closed. External adapter for operation from 115/230V 50-60 Hz.
Case:	Aluminum, with detachable cover. The front-panel components of the P-3500 should be protected when the instrument is exposed to extremely dusty environments. Plastic bags or dust-tight plastic enclosures will generally provide adequate protection.
Size and Weight:	
Size:	9 x 6 x 6 in *(230 x 150 x 150 mm)*
Weight:	6.3 lb *(2.9 kg)* including battery pack.

3.0 DESCRIPTION OF CONTROLS

3.1 GENERAL

The P-3500 has been specifically designed so that the operation of the front panel controls and push-button switches is straightforward and largely self-explanatory. The push buttons are color-coded and the operating mode can be immediately recognized. In addition, the first six push buttons are mechanically interlocked so that no improper operating mode can be selected. The two right-most push buttons select optional operating modes at the discretion of the user, and are of the alternate-action type.

The color coding of the push-button switches is such that the colors are displayed when the switches are depressed. The colors referred to in the following descriptions are those displayed when the respective switch is depressed.

The overall result of the color coding scheme is that:

(a) when blue is displayed, the instrument is off;

(b) when orange is displayed, the instrument is in a setup or diagnostic mode;

(c) when green is displayed, the instrument is in the normal measuring mode;

(d) when yellow is displayed, the instrument is in an optional mode of operation; i.e., FULL bridge and/or MULT X10.

3.2 POWER OFF – Blue

When the POWER OFF push button is depressed, primary power (battery pack or DC supply) is removed from all circuits. Power is turned on by depressing any one of the following five interlock push buttons.

3.3 AMP ZERO – Orange

When the AMP ZERO push button is depressed, the S+, S− inputs are disconnected from the bridge circuit and internally connected to signal common. The balance controls (coarse and fine) are also disabled. In this position, the AMP ZERO fingertip knob is adjusted for a ±0000 reading of the output display.

3.4 GAGE FACTOR – Orange

When the GAGE FACTOR push button is depressed, the instrument is configured so that the exact gage factor is displayed. The appropriate gage factor range is selected by the rotary switch adjacent to the gage factor potentiometer. The desired gage factor is set by the gage factor potentiometer and locked mechanically using the potentiometer locking mechanism.

3.5 RUN – Green

When the RUN push button is depressed, the instrument is configured to measure the strain as presented to the input terminals by the externally connected circuit. See Section 5.0 for details.

3.6 CAL – Orange

When the CAL push button is depressed, the internal calibration resistors are connected across the 120-ohm and 350-ohm dummy gages. Also, a contact closure is provided by pins **G** and **H** of the transducer connector. This contact closure may be used to implement various calibration arrangements; i.e., shunt active gage, shunt 1/2-bridge, transducer shunt calibration, etc. Care should be exercised, however, to insure that the relative merits or limitations of each arrangement are thoroughly understood. (Note: The resistors may also be placed on the P.C. board if desired. See Figure 2.)

3.7 BRIDGE EXCITATION OFF – Orange

When the BRIDGE EXCITATION OFF push button is depressed, bridge excitation is removed from P+ terminal, and the P+ terminal is connected directly to P–. The balance controls (coarse and fine) are also disabled. This position is not normally used if the remote-sense leads are connected. (See paragraph 6.6.).

3.8 MULT X1/X10 – Yellow

When the MULT push button is depressed, the full-scale range of the instrument is increased to ±199 990$\mu\epsilon$. The displayed reading must be multiplied by 10 to obtain the correct numerical value. This button is not interlocked, and is therefore selectable at the option of the user. (Note: The MULT push button has no effect on the displayed reading when GAGE FACTOR push button is depressed.)

3.9 FULL/ 1/2-1/4 – Yellow

When this push button is depressed, the internal 1/2-bridge is disconnected, and the instrument is in the FULL-bridge mode. This button is not interlocked, and is therefore selectable at the option of the user.

3.10 AMP ZERO Control

The AMP ZERO control is used to set the electrical zero of the amplifier when the AMP ZERO push button is depressed. The setting must not be changed during a reading or in any other operating mode. The control is operated by pressing lightly with the fingertip and rotating until displayed reading is ±0000. The AMP ZERO must be set with the MULT push button in the X1 position.

3.11 GAGE FACTOR Range Switch

The GAGE FACTOR range is selected by setting the rotary switch to the desired position. When gage factors of approximately 2.000 are being used, the 1.7-2.5 range will result in the optimum settability.

3.12 GAGE FACTOR Control

The exact value of gage factor is set by the 10-turn gage factor potentiometer. The locking mechanism provides a means to mechanically lock the knob in place.

3.13 BALANCE Range Switch

The BALANCE range is selected by setting the rotary switch to the desired position. The switch may be set to the zero position, in which case only the BALANCE potentiometer is active. Switch positions of $\pm 2000\mu\epsilon$, $\pm 4000\mu\epsilon$ and 0 are provided.

3.14 BALANCE Control

The BALANCE is set by the 10-turn BALANCE potentiometer. The potentiometer is locked in place by the locking mechanism.

3.15 ANALOG OUTPUT

The ANALOG OUTPUT is accessible via the front panel BNC connector. See Section 2.0 for output specifications.

3.16 ANALOG OUTPUT Level Control

The ANALOG OUTPUT level is variable over an 11:1 range by the fingertip adjustable level control. The control is operated by pressing lightly with the fingertip and rotating until the desired level is obtained.

3.17 INPUT CONNECTOR – DC Power

The female connector from the AC adapter plugs into the male receptacle in the upper-left corner of the instrument.

3.18 BATTERY Indicator

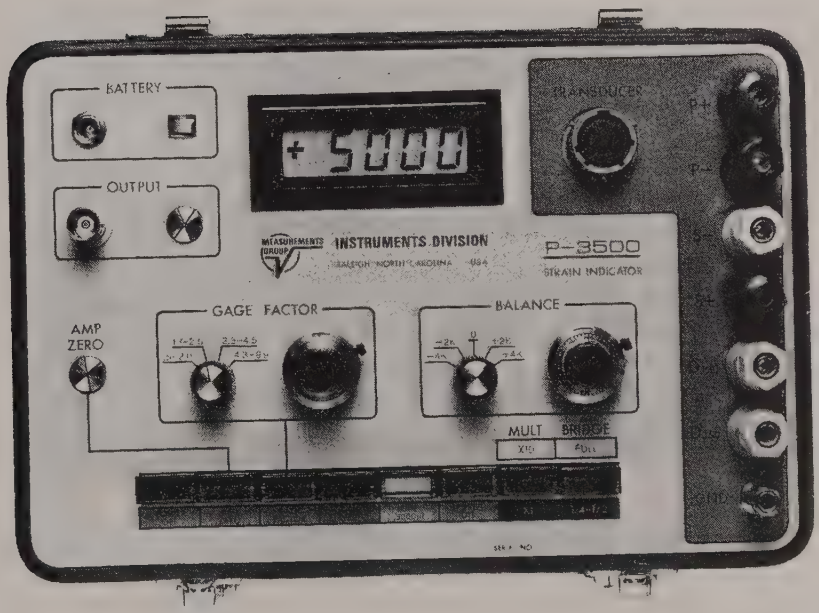
Battery condition is monitored (when the instrument is on) by the BATTERY indicator. If the meter deflects to the white area, the batteries are in satisfactory condition. When the meter falls to the white/red transition, battery charge is approximately 90% depleted and batteries should be replaced as soon as practical. ***Do not leave discharged batteries in the instrument for prolonged periods. Leakage can result in costly damage!***

3.19 BINDING POST Connectors

Strain gages are normally connected to the binding posts. See Section 5.0 for details.

3.20 TRANSDUCER Connector

Transducers are normally connected to the P-3500 via the front panel TRANSDUCER connector. In addition to the excitation and signal leads, remote-sense leads and connections for a remote calibration resistor are provided at this connector.



P-3500 Front Panel

4.0 OPERATING PROCEDURES – GENERAL

The P-3500 is designed for ease of operation – the push-button switches and front panel controls are arranged such that the proper setup procedure generally follows a straightforward left-to-right sequence. The steps outlined below are applicable to the use of the instrument as either a strain gage or transducer indicator. Specific details are covered in Sections 5.0 and 6.0.

4.1 Select FULL or 1/4-1/2 position of BRIDGE push button as required.

4.2 Select X1 position of MULT push button.

4.3 Connect strain gage(s) or transducer to binding posts or TRANSDUCER connector. (See instructions inside instrument cover or refer to Sections 5.0 and 6.0.)

4.4 Depress AMP ZERO push button. Allow instrument to warm up for two minutes minimum. Set AMP ZERO control for a readout display of ±0000. This adjustment must be made with MULT in X1 position.

4.5 (Depress GAGE FACTOR push button. Set GAGE FACTOR range switch and GAGE FACTOR control for the desired gage factor.

4.6 Depress the RUN push button. Set the BALANCE switch and the BALANCE control for a reading of ±0000. This setting must be made with the MULT in the X1 position.

4.7 Depress the CAL push button and verify calibration of the instrument. See paragraphs 5.5 and 6.5 for details.

4.8 Select the X1 or X10 MULT position as required.

4.9 Depress the RUN push button. Load the strain gage or transducer system and record the reading.

5.0 OPERATING PROCEDURES – STRAIN GAGE INPUTS

The operating procedures described in this section are intended for use with resistive strain gage inputs. The procedures in Section 4.0, ***Operating Procedures – General,*** are also applicable and should be consulted in conjuction with the procedures in this section.

5.1 INPUT CONNECTIONS – Strain Gage

Resistive strain gages are normally connected at the binding posts on the front panel. These binding posts are color-coded in accordance with conventional practice, and are clearly labeled. Input connections for full, 1/2- and 1/4-bridge configurations are shown on the inside cover of the instrument and also in Figure 1.

Connect the strain gage leadwires to the binding posts. Select the desired bridge configuration using the BRIDGE push button. Set the MULT push button to X1 position.

5.2 AMP ZERO – Orange

Depress the AMP ZERO push button. Allow the instrument to warm up for at least two minutes. Rotate the AMP ZERO fingertip control for a reading of ±0000. [To save time, instrument may be left in AMP ZERO position while gage(s) are being connected.]

5.3 GAGE FACTOR – Orange

Set the GAGE FACTOR switch to the desired gage factor range and depress the GAGE FACTOR push button. The gage factor will be displayed on the readout. Rotate the GAGE FACTOR potentiometer for the exact desired gage factor, and lock the control in place.

Normally this will be the gage factor given by the manufacturer on the engineering data sheet supplied with the strain gages. However, in some cases, the operator may calculate an "adjusted" gage factor to be used to compensate for the resistance of the leads connecting the strain gage to the P-3500.

Example: 350-ohm active gage, connected in three-wire 1/4-bridge configuration

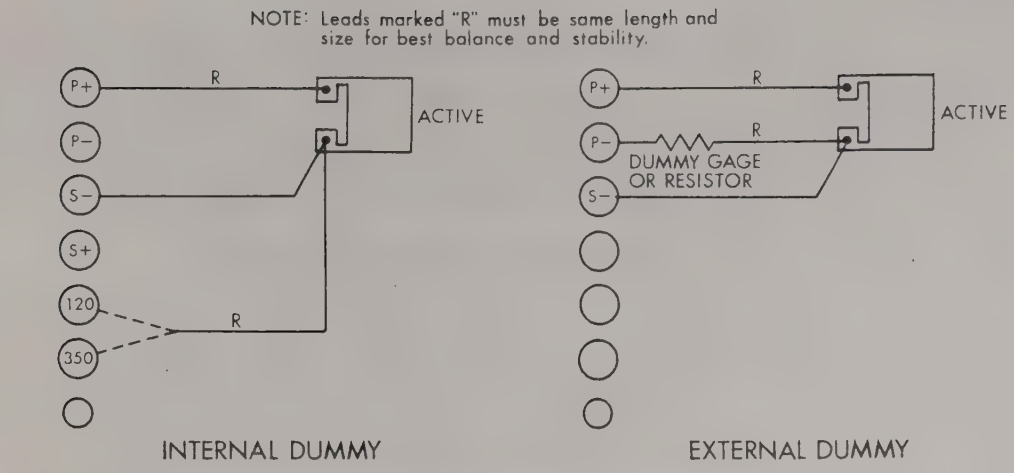
Leadwire resistance is 3 ohms in each lead. See Figure 1.

Gage Factor listed on package = 2.08

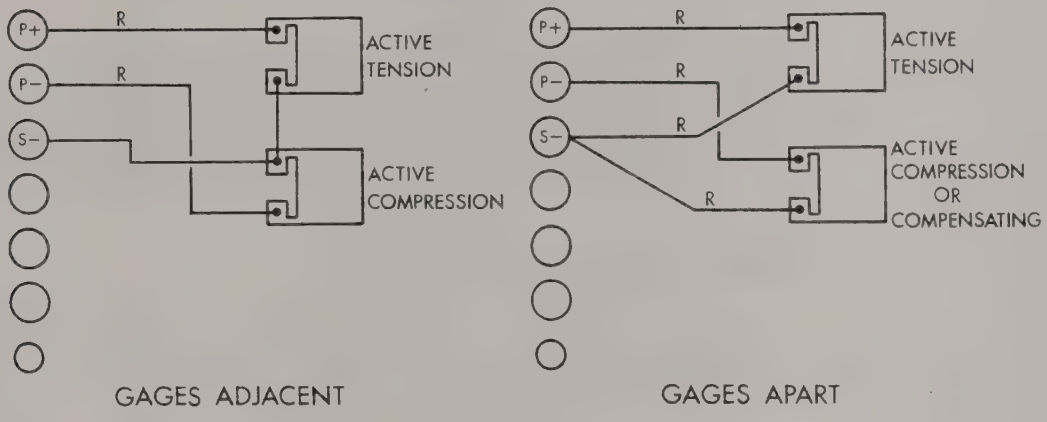
$$\text{Corrected Gage Factor} = \frac{350}{350 + 3} \times 2.08 = 2.062$$

The Gage Factor should be set to 2.062.

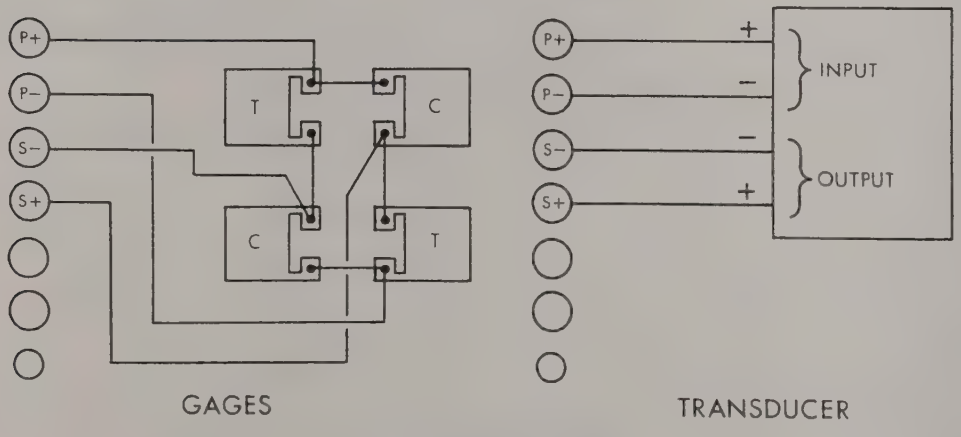
This procedure may be done automatically by using the Gage Factor control in conjunction with the CAL push button as explained in paragraph 5.5.



QUARTER BRIDGE



HALF BRIDGE



FULL BRIDGE

Figure 1: INPUT CONNECTIONS

5.4 RUN – Green

Select the X1 or X10 MULT position as required and depress the RUN push button. In this position all internal circuitry is configured to make an actual strain measurement. Set the BALANCE range switch and rotate the BALANCE potentiometer to obtain a reading of ±0000 with no load on the test structure.

The test structure may now be loaded and the reading recorded.

5.5 CAL – Orange

The P-3500 incorporates shunt calibration resistors across the internal 120-ohm and 350-ohm dummy gages. The calibration resistors simulate 5000$\mu\epsilon$ at a gage factor of 2.000. If the dummy gage (1/4 bridge) is being used, depress the CAL push button. The displayed reading will be 5000$\mu\epsilon$ x $\frac{2.000}{\text{GF Setting}}$ ±0.05% (assuming negligible lead resistance).

The shunt calibration resistors can be changed by the user to a value other than 5000$\mu\epsilon$ if desired. These resistors are insertable into turrets on the bottom of the main P.C. board. See Figure 2 for details.

When using 1/4-bridge configuration, the CAL position can also be used in conjunction with the GAGE FACTOR control to compensate for leadwire resistance. This procedure is as follows:

(a) Depress CAL push button.

(b) Calculate $\frac{2.000}{\text{Pkg. Gage Factor}}$ x 5000$\mu\epsilon$ = calibration number.

(c) Adjust GAGE FACTOR control to give reading of calibration number.

(d) Lock GAGE FACTOR control in place.

The P-3500 is now compensated for leadwire resistance. This is essentially the same procedure as explained in paragraph 5.3 above.

As previously noted (paragraph 3.6), the P-3500 provides a contact closure at pins **G** and **H** of the transducer connector for use in implementing various calibration arrangements. If an alternate calibration arrangement is desired, these connections are wired through the transducer plug to the appropriate points. The calibration resistor may be located external to the P-3500 or it may be installed on the P.C. board as shown in Figure 2. Figure 2 also shows the location of the calibration resistors which shunt the dummy 120-ohm and 350-ohm gages.

5.6 BR EXCIT OFF – Orange

If measurement appears noisy or unstable, depress BR EXCIT OFF push button. If the interference disappears, it is most likely of a

mechanical or load-related nature. If the interference is still present, it is most likely of an electrical nature; i.e., induced electrical noise, poor grounding or thermally induced offsets.

Offsets (thermal or other) may be measured as follows:

(a) Set the coarse BALANCE switch to 0.
(b) Set the fine BALANCE potentiometer to exactly 5.00.
(c) Depress BR EXCIT OFF push button.
(d) The displayed reading is the result of the extraneous offset. (If remote-sense leads are being used, see paragraph 6.6.)

5.7 MULT (X10–Yellow)

The MULT push button extends the measurement range of the instrument to ±199 990$\mu\varepsilon$ when in the X10 position. The operator selects the desired range in accordance with the expected strain reading.

AMP ZERO and BALANCE adjustments must be made with the MULT push button in the X1 position.

5.8 BRIDGE (Full–Yellow)

The BRIDGE push button configures the internal circuitry for FULL or 1/2-1/4 bridge operation. The operator selects the desired position in accordance with the bridge configuration currently in use.

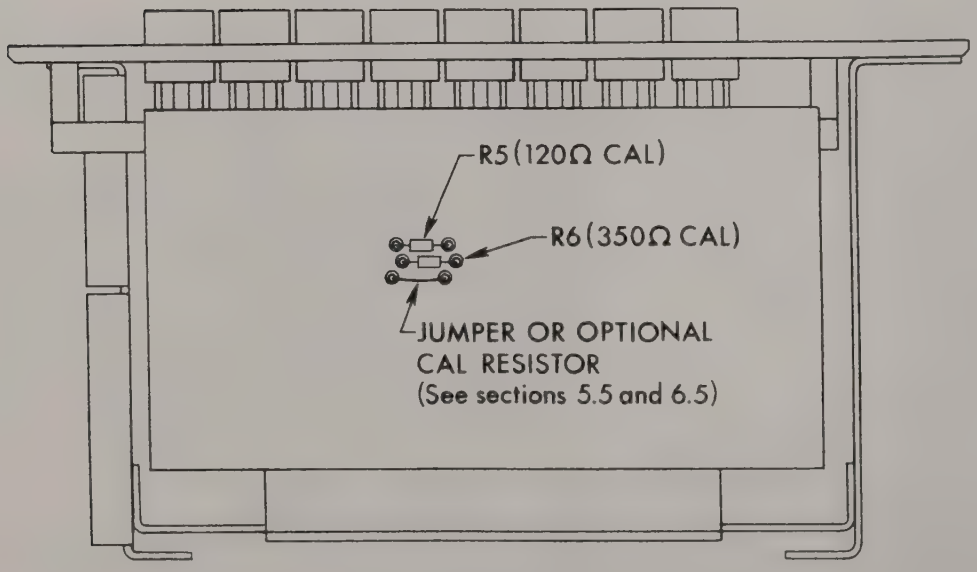


Figure 2

6.0 OPERATING PROCEDURES – TRANSDUCERS

In addition to providing transducer excitation voltage, and conditioning of the transducer output signal, the Model P-3500 incorporates specially designed remote-sense capability. The remote-sense circuitry varies the reference voltage to the A/D converter so as to give an accurate readout regardless of fluctuations in leadwire resistance. Remote-sense is activated by connecting pins **J** and **K** of the front panel transducer plug to the plus and minus excitation terminals **at the transducer**.

The Model P-3500 also provides a separate contact closure for remote shunt calibration. Wiring connections for the input connector are shown in Figure 3.

If desired, transducers may be connected to the front panel binding posts. However, remote-sense and remote calibration connections are accessible only at the transducer connector.

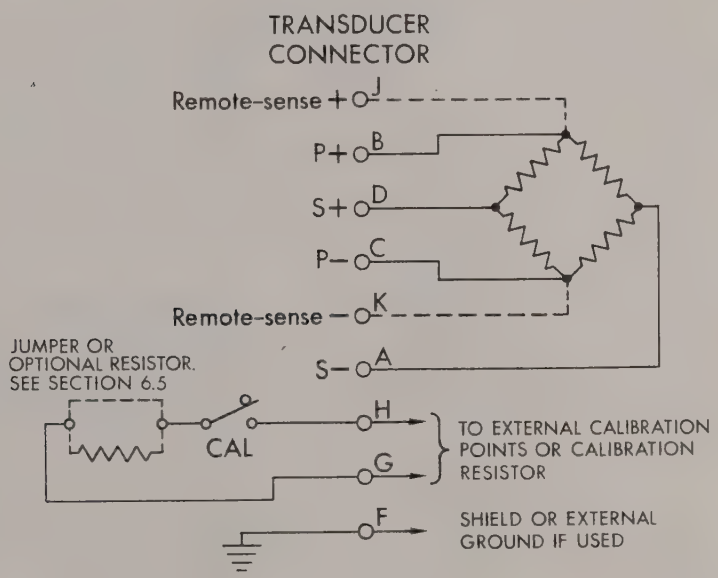


Figure 3

6.1 INPUT CONNECTIONS – Transducer

Set the BRIDGE push button to the FULL position. Connect the transducer to the instrument using the input plug. Spare plugs may be ordered from the Measurements Group (see parts list, Section 12).

Remote-sense connections are available at pins **J** and **K** of the input connector. If remote-sense is not to be used, these connections are not completed.

A contact closure from the CAL push button is also accessible at the transducer input connector. A remote resistor can be connected in series with pin **G** or **H** to facilitate calibration of the transducer according to the transducer manufacturer's recommendations. It is also possible to install the calibration resistor on the P-3500 circuit board. See Figure 2 for details.

6.2 AMP ZERO – Orange

Select the X1 MULT position and depress the AMP ZERO push button. Allow the instrument to warm up for at least two minutes. Rotate the AMP ZERO fingertip control for a reading of ±0000.

6.3 GAGE FACTOR – Orange

When using transducers, the gage factor may be set to give a readout in engineering units. The appropriate gage factor setting is calculated as follows:

Sensitivity of transducer, $\frac{mV}{V}$

FS = full-scale rating of transducer expressed in engineering units (psi, pounds, etc.)

GF = gage factor to be set on P-3500

$$GF = \frac{4000 \times \frac{mV}{V}}{FS}$$

The usable gage factor range of the P-3500 is 0.500 to 9.900. At gage factors <1.000 the readings may appear somewhat more unstable due to the high resolution. Therefore, it is recommended that the highest gage factor consistent with the required resolution be used. The examples below illustrate this procedure.

Example: Transducer sensitivity, 3.60 mV/V
Full-scale transducer rating is 20 000 psi

$$GF = \frac{4000 \times 3.6}{20\,000} = 0.720$$

The setting of 0.720 will operate satisfactorily, but the reading may appear unstable due to the low gage factor setting.

If a resolution of 10 psi is acceptable, the gage factor may be set to 7.20 and the readout will be 2000 counts. The reading must be multiplied by 10 to obtain the correct result in engineering units.

Example 2: Transducer sensitivity, is 1.80 mV/V
Full-scale transducer rating is 500 psi

$$GF = \frac{4000 \times 1.80}{500} = 14.40$$

A gage factor setting of 14.40 is not possible with the P-3500. Therefore, the gage factor would be set to 1.440 and the display would indicate 5000 counts. The resolution is, therefore, 0.1 psi. If this resolution is not required, the MULT push button may be set to X10 and the readout will be 500 counts, with a resolution of 1 psi.

Table 1 shows gage factor settings for several popular transducer sensitivities. If the gage factor is set for a displayed reading of greater than 6.000, the range restrictions as shown in paragraph 2.1 must be considered.

TABLE 1
GAGE FACTOR vs TRANSDUCER SENSITIVITY

FULL SCALE COUNTS	G.F. SETTING		
	TRANSDUCER SENSITIVITY IN mV/V		
	1.5 mV/V	2.0 mV/V	3.0 mV/V
1000	6.000	8.000	12.000
1200	5.000	6.667	10.000
1500	4.000	5.333	8.000
2000	3.000	4.000	6.000
2500	2.400	3.200	4.800
3000	2.000	2.667	4.000
4000	1.500	2.000	3.000
5000	1.200	1.600	2.400
6000	1.000	1.333	2.000
7000	0.857	1.143	1.714
8000	0.750	1.000	1.500
9000	0.667	0.889	1.333
10 000	0.600	0.800	1.200
12 000	0.500	0.667	1.000
15 000	0.400	0.533	0.800
20 000	0.300	0.400	0.600

$$FS = \frac{4000 \times \frac{mV}{V}}{GF} \qquad GF = \frac{4000 \times \frac{mV}{V}}{FS}$$

* See paragraph 6.3 for recommendations relative to gage factors of less than 1.000 or greater than 9.990.

Calculate the gage factor for the transducer in use.

Depress the GAGE FACTOR push button. Set the GAGE FACTOR switch to the appropriate range.

Rotate the GAGE FACTOR control for the exact desired gage factor, and lock the control in place.

6.4 RUN – Green

Depress the RUN push button. Rotate the BALANCE potentiometer for a display of ±0000. If necessary, adjust the BALANCE range switch to obtain this reading.

6.5 CAL – Orange

As noted in paragraph 6.1, a contact closure from the CAL push button is available at terminals **G** and **H** of the transducer connector. This feature will normally be used to implement shunt calibration of the transducer according to the transducer manufacturer's recommendation. The manufacturer will generally specify exactly how a specific value of shunt calibration resistor is to be connected. In some cases, the manufacturer may also supply leadwires, integral to the transducer assembly, which are to be used for this purpose. In any case, the transducer manufacturer's recommendations should be followed. The calibration resistor may be connected external to the P-3500 if desired, or in some cases where the P-3500 is essentially dedicated to the readout of a particular transducer, the calibration resistor may be installed on the P.C. board. See Figure 2 for details.

6.6 BR EXCIT OFF – Orange

Depressing the BR EXCIT OFF push button removes excitation from the transducer. Any residual reading will be the result of thermal or electrical offsets in the system. If it is desirable to measure such offsets, proceed as follows:

(a) Set coarse BALANCE switch to 0.
(b) Set fine BALANCE control to 5.00.
(c) Depress BR EXCIT OFF push button.
(d) The displayed reading is the result of the offset.

If remote-sense leads are connected, the displayed reading must be corrected by a factor directly related to the total resistance in the P+ and P- leadwires.

A contact closure from the CAL push button is also accessible at the transducer input connector. A remote resistor can be connected in series with pin **G** or **H** to facilitate calibration of the transducer according to the transducer manufacturer's recommendations. It is also possible to install the calibration resistor on the P-3500 circuit board. See Figure 2 for details.

6.2 AMP ZERO – Orange

Select the X1 MULT position and depress the AMP ZERO push button. Allow the instrument to warm up for at least two minutes. Rotate the AMP ZERO fingertip control for a reading of ±0000.

6.3 GAGE FACTOR – Orange

When using transducers, the gage factor may be set to give a readout in engineering units. The appropriate gage factor setting is calculated as follows:

Sensitivity of transducer, $\frac{mV}{V}$

FS = full-scale rating of transducer expressed in engineering units (psi, pounds, etc.)

GF = gage factor to be set on P-3500

$$GF = \frac{4000 \times \frac{mV}{V}}{FS}$$

The usable gage factor range of the P-3500 is 0.500 to 9.900. At gage factors <1.000 the readings may appear somewhat more unstable due to the high resolution. Therefore, it is recommended that the highest gage factor consistent with the required resolution be used. The examples below illustrate this procedure.

Example: Transducer sensitivity, 3.60 mV/V
Full-scale transducer rating is 20 000 psi

$$GF = \frac{4000 \times 3.6}{20\,000} = 0.720$$

The setting of 0.720 will operate satisfactorily, but the reading may appear unstable due to the low gage factor setting.

If a resolution of 10 psi is acceptable, the gage factor may be set to 7.20 and the readout will be 2000 counts. The reading must be multiplied by 10 to obtain the correct result in engineering units.

Example 2: Transducer sensitivity, is 1.80 mV/V
Full-scale transducer rating is 500 psi

$$GF = \frac{4000 \times 1.80}{500} = 14.40$$

7.0 USE WITH SEMICONDUCTOR STRAIN GAGES

The P-3500 is not specifically intended for use with semiconductor strain gages. However, the versatility of the instrument will allow it to be used satisfactorily in many cases.

The gage factor for most semiconductor strain gages is between 50 and 200, and is beyond the immediate range of the P-3500 gage factor controls. However, when the MULT push button is set to the X10 position, the gage factor range is effectively multiplied by 10, giving a range of 5.000 to 99.00. In this case, the readout is directly in microstrain with a resolution of 1$\mu\epsilon$.

For gage factors greater than 99.00 the following procedure may be used:

(1) Set the MULT push button to the X10 position.

(2) Mentally divide the desired gage factor by 100 and set the GAGE FACTOR controls for this value. Example: The gage factor is 180. Set the GAGE FACTOR controls for 1.800.

(3) The readout is now directly in microstrain with a resolution of 0.10$\mu\epsilon$; i.e., the actual reading is the displayed reading divided by 10.

Note that the full-scale range of the instrument is now $\pm$1999.9$\mu\epsilon$.

The range restrictions as specified in paragraph 2.1 apply to both the above cases. If the GAGE FACTOR control is set for a displayed gage factor greater than 6.000, this restriction must be considered.

The BALANCE range of the P-3500 will generally not be adequate for semiconductor strain gages. The user will sometimes find it desirable to provide external bridge completion components and external balance networks. Consult the semiconductor strain gage manufacturer for recommendations.

8.0 ANALOG OUTPUT

The P-3500 is equipped with an analog output accessible via the BNC connector on the front panel. The output level is 40 $\mu V/\mu\epsilon$ (or 40 μV/count if using transducers) when the output level control is set at minimum. This level can be increased to a maximum of 440 $\mu V/\mu\epsilon$ with output level set to maximum.

The analog output is intended primarily to allow monitoring of the signal using an oscilloscope or recorder. Bandwidth is DC to 4 kHz −3 dB.

The analog output level is always linearly related to the digital display. Therefore, it is possible to simulate any desired level of output for strain or transducer measurements by using the BALANCE control. Using this procedure, the balance controls are used to obtain a digital display of the desired reading. Subsequently, the ANALOG OUTPUT level control and/or the input level control of the external readout device are used to obtain the desired display on the external readout device. This procedure will work equally well with external oscilloscopes, strip chart recorders, digital voltmeters, peak reading voltmeters, etc.

9.0 OPTIONAL ACCESSORIES

9.1 AC ADAPTER

An AC adapter is available for operation from the AC power line. When the cord from the adapter is plugged into the front panel connector of the P-3500, the internal battery pack is automatically disconnected. A separate power supply is used for 115 Vac, 60 Hz operation and 230 Vac, 50 Hz operation.

	Part Number
115 Vac, 60 Hz	100-121299
230 Vac, 50 Hz	100-121300

When the AC adapter is used, it is advisable to use a good quality AC line filter and/or isolation transformer. This practice will minimize interference from the AC line. Such interference will be most evident on the analog output when making very low level strain readings.

9.2 TRANSDUCER CONNECTOR

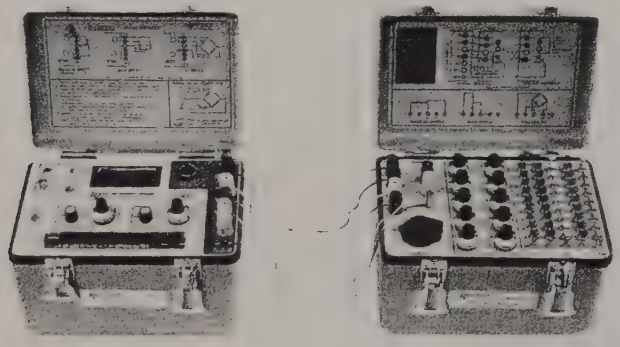
The input plug for mating to the transducer connector may be ordered from the Measurements Group or an electronic parts distributor.

Measurements Group Part Number 12X300515
Bendix PT06A-12-10P(SR)

9.3 USE OF SB-10 WITH P-3500

The Model SB-10 Switch and Balance Units can be used to switch up to 10 separate channels to the P-3500 input terminals. This is accomplished by connecting the front panel binding posts of the P-3500 to the corresponding front panel binding posts of the SB-10.

NOTE: The SB-10 is the newest in the Measurements Group series of switch and balance units. The operating characteristics are generally the same as those of earlier design, i.e., SB-1, SB-1L, SB-1K, used with the P-3500.



When using the SB-10 with the P-3500, the following considerations must be applied:

(a) When intermixing 120-ohm and 350-ohm 1/4 bridges, the interconnecting leadwire from the SB-10 "D EXT" terminal must be manually moved to the appropriate dummy binding post on the P-3500.

(b) When intermixing full and 1/2-1/4 bridges, the FULL 1/2-1/4 push button on the P-3500 must be switched to the appropriate position for the respective input configuration.

(c) When using the SB-10, the coarse BALANCE switch of the P-3500 must be set to 0, and the fine BALANCE control of the P-3500 must be set to 5.00. The balance controls of the SB-10 are used for initial bridge balance and the P-3500 balance controls have no effect.

Figure 4 shows the interconnections between the P-3500 and the SB-10.

NOTE: More detailed instructions for use of the SB-10 are given in the separate instruction manual supplied with that instrument.

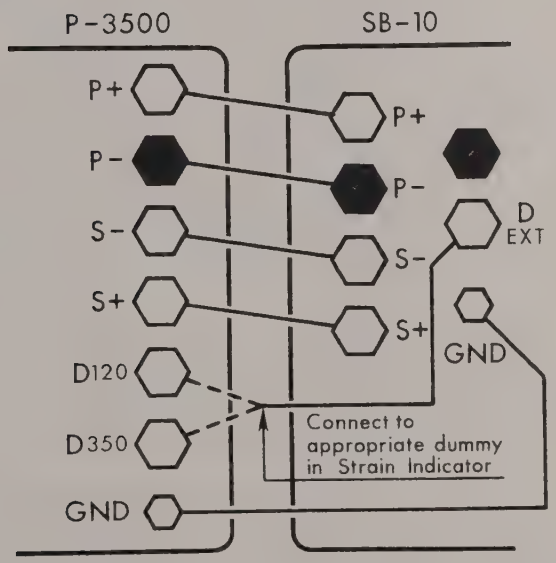


Figure 4

10.0 MAINTENANCE AND CIRCUIT DESCRIPTION

10.1 BATTERY REPLACEMENT

Battery condition is monitored by the miniature front panel meter when the P-3500 is "on". The pointer will normally indicate in the white region. When the pointer falls to the red/white transition, the batteries are approximately 90% depleted and should be replaced as soon as practical. To replace the batteries, proceed as follows:

(1) Remove the four screws from the bottom of the case and remove the instrument from the case.

(2) Place the battery compartment so that the two screws that retain the circuit board are accessible, and remove both screws.

(3) Note battery polarity. Remove old batteries and replace with new batteries. OBSERVE CORRECT POLARITY.

(4) Reassemble in the reverse order.

10.2 CIRCUIT DESCRIPTION

The following circuit description and the attached schematic diagram are intended to aid the technician in the diagnosis and repair of the P-3500.

10.2a POWER AND EXCITATION CIRCUITS

The P-3500 is powered from the 9 Vdc battery pack through the DC input connector J9. When the external AC adapter is used, it is also connected through J9 and the battery is automatically disconnected. Voltage from connector J9 is applied to the power switch, SIA. When SIA is on, voltage is applied to the front panel battery indicator through R24 and CRI, and to the stable reference source U4. The output of U4 is 2.500V ±0.025V at TP1, and this output is used as a stable reference source for U5 and U6. U5 is a 723 type regulator that supplies +5 Vdc to all operational amplifiers. The output of U6 is adjusted by R30 for 2.000 V at TP2. This voltage is the regulated P+ excitation supply for the instrument. The P− lead is connected to the negative side of the battery and to the chassis ground.

The +5V supply is also used to power the digital panel meter, Z1. The digital panel meter has a built-in positive-to-negative converter which provides −5 Vdc at pin A15. This converter is reinforced by another positive-to-negative converter, U3, which operates from the +5V supply. The −5 Vdc outputs from U3 and the digital panel meter are combined to provide the −5V supply for the operational amplifiers. (The −5V supply will actually measure −4.8 to −4.9V.) Capacitors C8, C9 and C10 are filter capacitors to reduce

noise from the input power supply and the internal positive-to-negative converters.

10.2b BRIDGE COMPLETION AND CALIBRATION COMPONENTS

Bridge completion components R2 and R4, located on the bridge completion gage block, make up the 350-ohm internal 1/2-bridge. When 1/2-or 1/4-bridge operation is selected by S1-H, the center point of R2 and R4 is connected to S+. In the full bridge position, this center point is disconnected and the half bridge has no effect on the operation of the instrument. R1 and R3 are the 120-ohm and 350-ohm internal dummy gages.

R5 and R6 are internal shunt calibration resistors. These resistors are shunted across the internal dummy gages whenever the CAL switch is depressed. If desired, a calibration resistor may be connected through contacts **G** and **H** of the transducer. All calibration resistors are connected to turrets on the bottom side of the main switch board, and can be easily changed by the user to accommodate various specific requirements.

10.2c INPUT AMPLIFIER

The input amplifier consists of dual operational amplifier U1, and single operational amplifier U2. In the AMP ZERO mode, the inputs are connected directly together and to P– through R7 and R8. In this mode, AMP ZERO control R45 is adjusted for an exact ±0000 reading on the display.

Gain of the amplifier is determined by the setting of the MULT push button, R13 determines the gain on X1 setting; R14 determines the gain on X10 setting. U2 is the common-mode amplifier, and has a nominal gain of 1.12 to give an adequate overall adjustment range for the instrument. Potentiometer R21 is adjusted for maximum common-mode rejection at 60 Hz. The network composed of R24, R25 and R26 provides span adjustment of the instrument.

The output of the amplifier is applied to the input of the digital panel meter through the gage factor push button switch. This output is applied to the digital panel meter at all times except in the GAGE FACTOR mode.

10.2d GAGE FACTOR AND BALANCE

Excitation voltage is applied to an isolation amplifier consisting of U11a and U11b. The output of this amplifier is applied to the balance network consisting of R46 through R56. Switch S3 is the coarse BALANCE switch, and potentiometer R54 is the 10-turn fine balance control.

The outputs from the balance network are fed through two additional isolation amplifiers, U10a and U10b. The outputs of U10a and U10b are fed through R9, R10, R11 and R12 to the inverting inputs of the input amplifier. R42 is used to correct the output of the balance network for any offset voltages in U10 or U11. R45 is the front panel AMP ZERO control.

The outputs of U11a and U11b are also applied to U11c. U11c removes any existing common-mode component so that the output of U11c is referenced to P– (battery negative and chassis ground). This output is used to drive that gage factor network consisting of R63 through R70 and the GAGE FACTOR control, R71. When the GAGE FACTOR push button is depressed, the full output from U11c is applied to the reference input of the digital panel meter.

The output from the wiper of GAGE FACTOR control R71 is applied to the analog-high input of the digital panel meter. The voltage level at the wiper of R71 is determined by the setting of GAGE FACTOR range switch S2, and the setting of the GAGE FACTOR control. The digital panel meter will indicate the gage factor with the decimal point properly positioned.

When any push button other than GAGE FACTOR is depressed, the reference input of the digital panel meter is fed from the wiper of the GAGE FACTOR control, and the analog-high input of the digital panel meter is fed from U2.

10.2e ANALOG OUTPUT

The analog output from the input amplifier is fed from the junction of R25 and R26 to the input of an active low-pass filter, U12. The output of U12 is fed to a non-inverting follower amplifier U13. The output of U13 can be adjusted over an 11 to 1 range by the front panel control R74. The analog output appears at the front panel BNC connector, J10.

11.0 CALIBRATION PROCEDURE

Calibration of the P-3500 is most easily accomplished using the Measurements Group Model 1550A Strain Indicator Calibrator. A digital voltmeter with accuracy of approximately ±0.01% and a resolution of at least 100μV on a 2V scale is also required.

The P-3500 is specified to a basic accuracy of ±0.05%. Since the Model 1550A is specified to an accuracy of ±0.02%, the tolerances outlined in the following calibration procedure are reduced to ±0.03% to guarantee published accuracy of the P-3500.

If the Model 1550A is not available, other types of mV/V calibrators may be used. The user is cautioned, however, that it is necessary to understand both the mV/V calibrator, and the ratiometric nature of the measurement made by the P-3500, before attempting to calibrate the instrument. Figure 5 shows the locations of the calibration controls referred to in the calibration procedure.

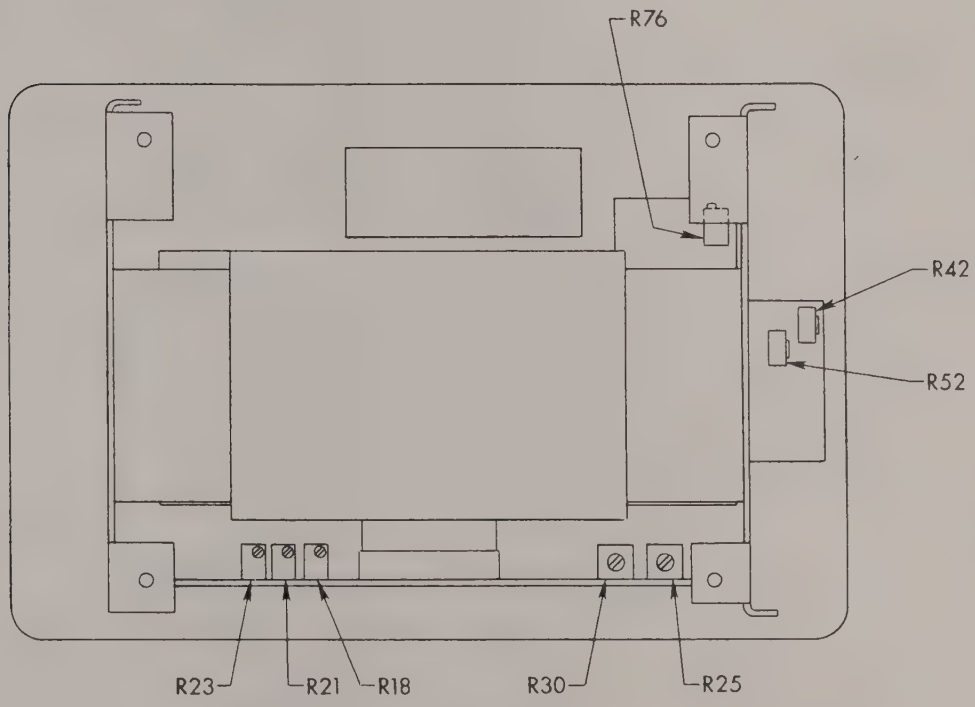


Figure 5

11.1 PRELIMINARY PROCEDURE

Remove the P-3500 from its case. Verify that the battery is in satisfactory condition, and that the instrument is functional in all basic operating modes. The following procedure assumes that there are no functional problems and the primary purpose is to calibrate the instrument.

Remove the battery pack by removing the four retaining screws in the side panels. Position the battery pack to permit access to the circuit boards.

Connect the 350-ohm section of the 1550A to the P-3500 binding posts in the full-bridge configuration. Use 20 AWG [0.032 in *(0.813 mm)*] or larger wire diameter and keep all leads less than one foot in length. Set the 1550A to 350 ohm and the polarity to "+". In the following procedure, a reading from the digital voltmeter (DVM) is specifically referred to as "DVM reading". A reading from the P-3500 display is specifically referred to as "a reading of XXXX".

11.2 EXCITATION

(a) Depress AMP ZERO push button.

(b) Connect DVM from P+ to P− terminals of P-3500.
Adjust R30 for DVM reading of 2.0000 ±0.1mV.

11.3 ZERO ADJUSTMENTS

(a) Connect the DVM from pin 1 to pin 7 of U10.
Set AMP ZERO control to mid-scale.
Adjust R42 for DVM reading of 0000 ±10μV.
Remove DVM.

(b) Depress GAGE FACTOR push button.
Adjust GAGE FACTOR control for a reading of 2.000.
Lock GAGE FACTOR control in place.

(c) Depress AMP ZERO push button.
Set MULT push button to X10.
Adjust R23 for a reading of 0000 ±0.

(d) Set MULT push button to X1.
Adjust R18 for a reading of 0000 ±0.

(e) Repeat (c) and (d) until there is no change in reading when MULT is switched between X1 and X10.

(f) Connect DVM directly across Anlaog Output, J10.
Set MULT push button to X1.
Set OUTPUT level control to maximum CCW position.
Adjust R76 for a DVM reading of 0000 ±10μV
Remove DVM.

(g) Short the S+ to the S− binding post of the P-3500. (Leave the 1550A connected.) Use a 20 AWG [0.032 in *(0.813 mm)*] or larger wire diameter and tighten binding posts securely.
Depress RUN push button. Set BRIDGE push button to FULL.

Set BALANCE switch to 0 position.

Set BALANCE control to exactly 5.00 and lock in place.

Adjust R52 for a reading of 0000 ±1.

Remove S+, S− short.

11.4 SPAN ADJUSTMENTS

(a) Depress AMP ZERO push button. Adjust AMP Zero control for a reading of 0000 ±0.

(b) Depress GAGE FACTOR push button. Verify that gage factor is exactly 2.000. Lock GAGE FACTOR control in place.

(c) Set 1550A to 000$\mu\epsilon$.

(d) Depress RUN push button. Adjust BALANCE control for a reading of 0000 ±1. Lock BALANCE control in place.

(e) Set MULT push button to X1 position.

Set 1550A to 19 900$\mu\epsilon$.

Adjust R25 for a reading of 19 900 ±6.

(f) Set MULT push button to X10. Set 1550A to 60 000$\mu\epsilon$. Reading should be 6000 ±3.

(g) If the readings of (e) and (f) above do not track properly, it will be necessary to determine which gain position (X1 or X10) is too **low** and to increase that gain accordingly.

Pads are provided on the bottom of the P.C. board directly under gain determining resistors R13 (X1) and R14 (X10). After determining which gain position is **low**, connect a padding resistor across the appropriate gain determining resistor. If a padding resistor is required, it will normally be in the 500K to 2 megohm range. Use only low-temperature-coefficient (<100 ppm/°C) resistors. After the gain is changed, repeat steps (e) and (f) until tracking is accurate.

11.5 FINAL CHECKS

(a) Set MULT push button to X1.

Perform the following checks:

1550A Setting ($\mu\epsilon$)	Reading	Tolerance*
0000	0000	±1
100	100	±2
500	500	±2
1000	1000	±2
5000	5000	±4
10 000	10 000	±5
19 000	19 000	±8

* Tolerances are computed to be ±0.03% rdg ±2 counts.

(b) Set MULT push button to X10.
Perform the following checks:

1550A Setting ($\mu\epsilon$)	Reading	Tolerance*
0000	0000	±0
20 000	2000	±2
40 000	4000	±2
60 000	6000	±3
80 000	8000	±3
90 000	9000	±4

* Tolerances are computed to be ±0.03% rdg ±1 count.

(c) Set MULT push button to X1. Set 1550A to 18 000$\mu\epsilon$. Vary the gage factor settings as per the table below and check readings.

Gage Factor	Reading $\mu\epsilon$	Tolerance*
2.000	18 000	±8
3.000	12 000	±6
4.000	9000	±5
6.000	6000	±4
8.000	4500	±3
9.000	4000	±3

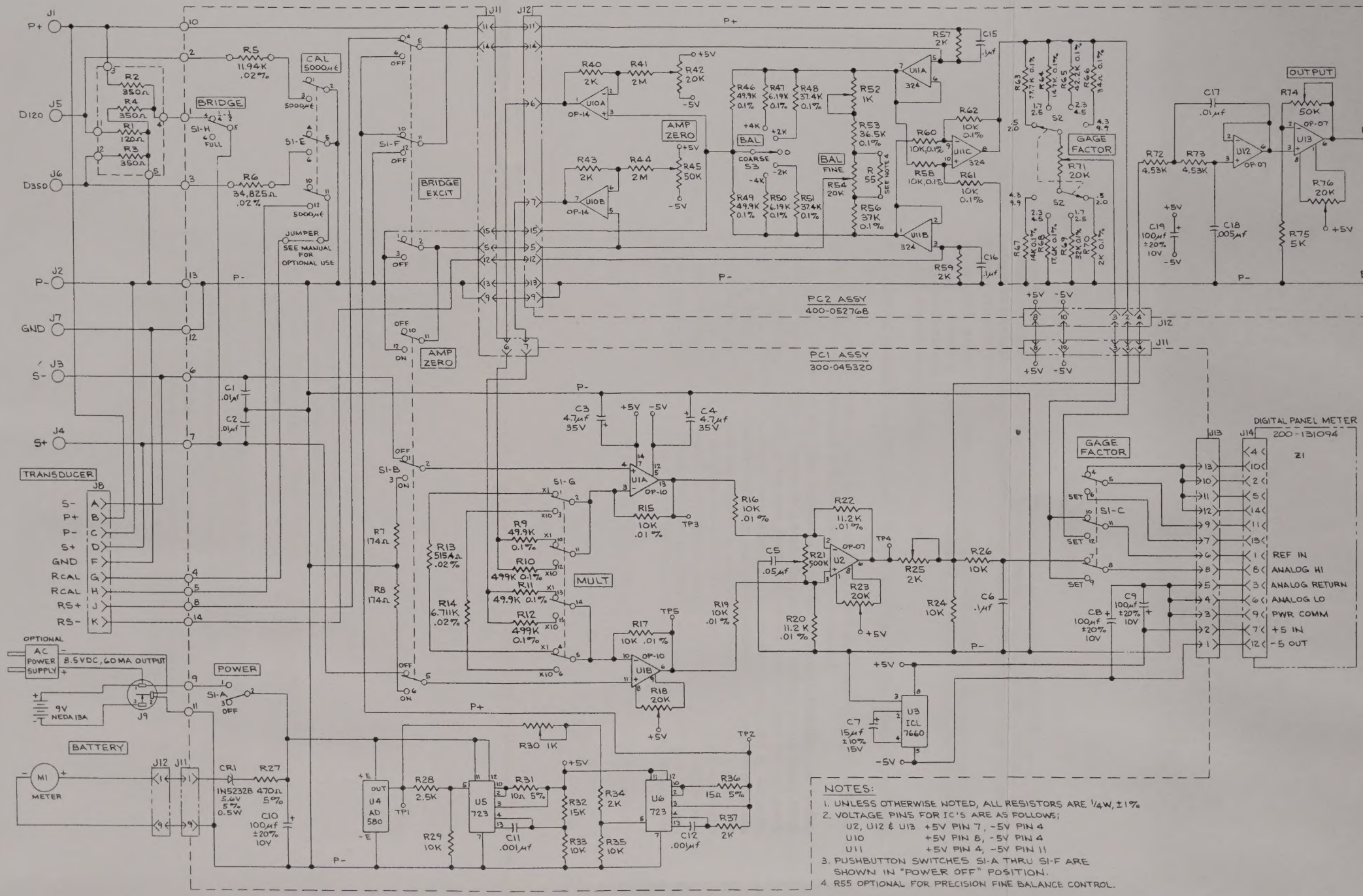
* Tolerances are computed to be ±0.03% rdg ±1 count.

(d) Depress POWER push button. Disconnect 1550A. Reassemble instrument.

12.0 REPLACEMENT PARTS

Schematic Designation	Description	MG Part Number
U1	Dual Matched Amplifier, OP-10EY	14X700100
U2, U12, U13	Amplifier, OP-07DP, Precision Monolithics	14X700087
U3	Voltage Converter, ICL7660, Intersil	14X700101
U4	Voltage Reference, AD580J, Analog Devices	14X700070
U5, U6	Voltage Regulator, LM723N, National Semiconductor	14X700040
U10	Amplifier, OP-14CP, Precision Monolithics	14X700095
U11	Quad Amplifier, LM324N, National Semiconductor	14X700068
B1	Batteries, Alkaline D cells, Eveready E-95 or equal (six required)	23X300001
	Spare Input Plug (Measurements Group)	12X300515
	Spare Input Plug (Bendix) PTO6A-12-10P(SR)	
	AC Adapter, 115 Vac, 60 Hz	100-121299
	AC Adapter, 230 Vac, 50 Hz	100-121300

If other replacement parts are required, they may be obtained by specifying the instrument model number, serial number, part description and schematic designation. Contact Measurements Group Applications Engineering if assistance is required.



NOTES:
1. UNLESS OTHERWISE NOTED, ALL RESISTORS ARE 1/4W, ±1%
2. VOLTAGE PINS FOR IC'S ARE AS FOLLOWS;
   U2, U12 & U13 +5V PIN 7, -5V PIN 4
   U10 +5V PIN 8, -5V PIN 4
   U11 +5V PIN 4, -5V PIN 11
3. PUSHBUTTON SWITCHES S1-A THRU S1-F ARE SHOWN IN "POWER OFF" POSITION.
4. R55 OPTIONAL FOR PRECISION FINE BALANCE CONTROL.

These drawings and specifications are intended to provide information for the proper utilization or maintenance or calibration or repair of the items represented. They are, and shall remain the property of the Measurements Group, and shall not be reproduced or copied, in whole or in part, as the basis for manufacture or sale of such item.

MEASUREMENTS GROUP, INC.

400-052775F

SCHEMATIC
DIGITAL STRAIN INDICATOR
P-3500

WARRANTY

Measurements Group, Inc., warrants all instruments it manufactures to be free from defect in materials and factory workmanship, and agrees to repair or replace any instrument that fails to perform as specified within one year after date of shipment. This warranty shall not apply to any instrument that has been:

i) repaired, worked on or altered by persons unauthorized by the Measurements Group in such a manner as to injure, in our sole judgment, the performance, stability, or reliability of the instrument;

ii) subjected to misuse, negligence, or accident;
or

iii) connected, installed, or used otherwise than in accordance with the instructions furnished by us.

At no charge, we will repair, at our plant, or an authorized repair station, or at our option, replace any of our products found to be defective under this warranty.

This warranty is in lieu of any other warranties, expressed or implied, including any implied warranties of merchantability or fitness for a particular purpose. There are no warranties which extend beyond the description of the face hereof. Purchaser acknowledges that all goods purchased from Measurements Group are purchased as is, and buyer states that no salesman, agent, employee or other person has made any such representations or warranties or otherwise assumed for Measurements Group any liability in connection with the sale of any goods to the purchaser. Buyer hereby waives all rights buyer may have arising out of any breach of contract or breach of warranty on the part of Measurements Group, to any incidental or consequential damages, including but not limited to damages to property, damages for injury to the person, damages for loss of use, loss of time, loss of profits or income, or loss resulting from personal injury.

Some states do not allow the exclusion or limitation of incidental or consequential damages for consumer products, so the above limitations or exclusions may not apply to you.

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The Measurements Group reserves the right to make any changes in the design or construction of its instruments at any time, without incurring any obligation to make any change whatever in units previously delivered.

The Measurements Group's sole liabilities, and buyer's sole remedies, under this agreement shall be limited to the purchase price, or at our sole discretion, to the repair or replacement of any instrument that proves, upon examination, to be defective, when returned to our factory, transportation prepaid by the buyer, within one year from the date of original shipment.

Return transportation charges of repaired or replacement instruments under warranty will be prepaid by the Measurements Group, Inc.

The Measurements Group is solely a manufacturer and assumes no responsibility of any form for the accuracy or adequacy of any test results, data, or conclusions which may result from the use of its equipment.

The manner in which the equipment is employed and the use to which the data and test results may be put are completely in the hands of the purchaser. Measurements Group, Inc., shall in no way be liable for damages consequential or incidental to defects in any of its products.

This warranty constitutes the full understanding between the manufacturer and buyer, and no terms, conditions, understanding, or agreement purporting to modify or vary the terms hereof shall be binding unless hereafter made in writing and signed by an authorized official of Measurements Group, Inc.

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